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MODEM 2400

by

Barbara Kierkowska



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MODEM 2400

Barbara Kierkowska, engineer

1. Introduction

Data transmission, constituting a new telecommunications service, is realized on remote data transmission lines. Remote data transmission lines must satisfy CCITT recommendations for tele-engineering parameters. Modems (signal converters) constitute the terminals of remote data transmission lines.

Lines in telecommunications networks as well as links in new lines specially built for these purposes can be used for data transmission.

Data transmission lines can be subdivided from the standpoint of data transmission rates as follows: up to 300 baud, up to 1200 bits/s, up to 2400 bits/s, up to 4800 bits/s, up to 9600 bits/s, up to 24,000 bits/s, and up to 48,000 bits/s.

The second criterion for subdividing data transmission lines is the method of establishing the connection. The line can be established permanently and leased to a user or it can be commutated, i.e., established via automated telephone exchanges from randomly selected partial lines. The quality of leased-out lines is definitely superior to the quality of

commutated lines, on the other hand, the advantage of commutated lines is their low cost to the user and the possibility of better utilization of lines for telecommunications purposes in the event of low utilization for data transmission.

Finally, the last subdivision used is the type of transmission: simplex, half-duplex, and duplex.

Operation in a simplex realizes data transmission only in one direction e.g., from a terminal to the computer. Operation in a half-duplex realizes data transmission in both directions, however, alternately (not simultaneously). Operation in a duplex allows us to operate in both directions simultaneously. Selecting the appropriate variant among those mentioned, we use modems satisfying these requirements.

The structural designs of modems depend on the producer, whereas the selected method for converting signals depends on the data transmission rate. Thus, modems up to 1200 bits/s operate with frequency modulation whereas modems with a rate 2400 bits/s and 4800 bits/s operate with phase modulation, while modems with a rate 2400 bits/s operate on the di-bit principle, and modems with a 4800 bits/s rate operate on the tri-bit principle.

Modems with a modulation rate 2400 bits/s, manufactured in the country and imported, are permitted to operate in the Polish remote data transmission network.

The most frequently used imported modems include:

| Company | Type of modem |
|-------------------------------------|---------------|
| International Business Machines | 3072 |
| I M Ericsson | EAT 2400 |
| Standard Radio and Telefon ITT | EAT 2400-4 |
| Telecommunications Radioteletriques | GH 3004 |
| Siemens | SEMATRANS |
| | 2400 |
| | 2400 |

The Greater Polish TELKOM-TELETRA Teleelectronic Communications Plants in Poznan are the Polish producer of modems.

After type 8006 EC modems 600/1200 bits/s were elaborated and production was started, the production of modems 1200/2400 bits/s began.

The conceptual and systems design of these modems originated in the Teleelectronic Communications Institute of the Warsaw Institute of Technology. The design was verified in practice by the designer of the user model. The prototypes of the modem built in the TELKOM-TELETRA Plants took into account optimization of the results of tests performed on the user model. This year the TELKOM-TELETRA Plants began to introduce the production of the modem and serial production is anticipated in the fourth quarter of 1977.

Modem 2400, which was discussed in this article, is manufactured by the SIEMENS company and used in the domestic remote data transmission network in remote data processing systems.

2. Modem 2400 - technical data

A modem (modulator-demodulator) makes it possible to transmit binary digits over a telephone line at a maximum rate of 2400 bits/s. Modem 2400 can be used for operation on permanent (leased) or commutated lines. It operates on the four-phase difference modulation principle.

Technical data:

| | |
|-------------------------|---|
| transmission rate..... | 2400, 1800, or 1200 bits/s* |
| carrier frequency..... | 1800 Hz |
| type of modulation.... | four-valued phase difference modulation |
| Operating regime..... | full-duplex or half-duplex |
| Transmission level..... | regulation in steps by 1 dBm 0-15 dBm |
| Arrival level..... | 0-43 dBm |
| Transmission..... | Serial |

*CCITT recommendations for modem 2400 do not specify a rate of 1800 bits/s.

Additional equipment: telephone for conversations in "stiff" connections or auxiliary channel.

3. Modem - transmitter (coder and modulator)

Operational principle of four-phased difference modulation.

A transmission rate of 2400 bits/s is obtained by combining successive sequential bits in pairs of bits called di-bits. To each pair of bits corresponds one or four possible phase shifts of the signal carrier frequency (1800 Hz). This assignment is presented in Tables 1 and 2.

From the tables it follows that the assignment of di-bits is not a rule and that it depends on the type and operational alternative of the modem.

The generated two-band signal with a damped carrier frequency, which is 1800 Hz, lies in the middle of the natural conversational transmission band and is delivered to the line. The information is recovered in the receiver by comparing the preceding and succeeding phases (i.e., the carrier phase at the modulation instant).

Table 1. Assignment of Di-bits to Phase Changes, Datel Modem No. 7A

| Di-bit (a) (Pair of bits) | (b) Phase change |
|------------------------------|------------------|
| 00 | 0° |
| 10 | -90° |
| 11 | -180° |
| 01 | -270° |

Key: (a) Di-bit (pair of bits)
(b) Phase change

In modulation techniques, pairs of elements of a data signal are identified by changes in the carrier phase of the signal. The principle of this modulation technique requires that transmission be synchronized,

Table 2. Assignment of Di-bits to Phase Changes, Modem 2400/4, manufactured by Siemens Company

| Di-bit | Zurbaan Pasy | |
|---------------|--------------|-----------|
| | (b) | |
| (Pair Di-bit) | Variant A | Variant B |
| (a) | (c) | (d) |
| 00 | 0° | +45° |
| 01 | +90° | +135° |
| 11 | +180° | -135° |
| 10 | -90° | -45° |

Key: (a) Di-bit (pair of bits)
 (b) Phase change
 (c) Variant A
 (d) Variant B

i.e., that the modulator and demodulator be controlled by clock strobing in such a way that individual elements of this data signal can be properly identified during demodulation.

Fig. 2 presents indicator diagrams of phases illustrating the quadrature technique used to generate a four-phase difference modulated signal.

Two two-band ring-shaped modulators are used. A bipolar modulating signal with a constant amplitude applied to any of these modulators causes multiplication of the carrier frequency either by +1 or by -1; hence, the output carrier frequency undergoes a 180° phase shift (Fig. 2a).

1800 Hz carrier frequencies are delivered to two modulators and therefore output phases of modulators of channels P and Q are possible as shown in Fig. 2a and 2b.

The outputs of modulators P and Q have the same amplitude and the phase relations described above can be added, after which they form a linear signal, one of the four phases of which is shifted by 90° (Fig. 2c).

Solutions of this diagram indicate that the -90° phase shift was achieved by phase inversion of a channel. The task of the encoding logic is to test each pair of successive bits (di-bits) in the data flow to be

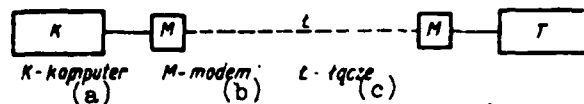


Fig. 1. Simplified schematic diagram of remote transmission line between terminal communicating with a computer

Key: (a) computer
(b) modem
(c) line

transmitted, determining the required phase shift and generating the polarization changes at the outputs to modulators P and Q.

These polarization changes (so-called modulating signal) depend on two factors, namely, the di-bit to be transmitted and the current state of the channels.

Polarization changes (so-called modulating signal) are generated by a system of gates, which compare the di-bit information stored in a two-stage shift register (released by means of bit-by-bit strobing) with information about the state of the channels stored in a pair of bistable elements and

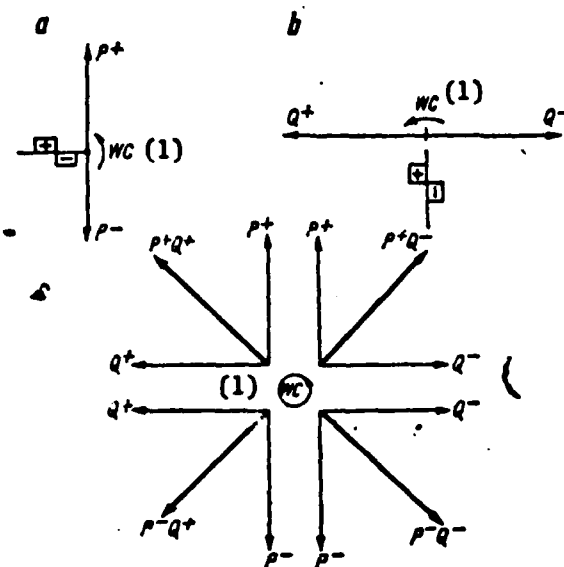


Fig. 2. Indicator diagrams

Key: (1) output frequency

released by means of di-bit strobing. The described coding process requires that the system operate synchronously. To ensure that every di-bit is determined, the coding device must have the capability to predict sampling instants. The passages of the data signal in terminal devices are equalized by a positive leading edge of the clock strobing pulse, so that negative leading edges occur among data signal elements, i.e., at sampling instants, which is shown in Fig. 3.

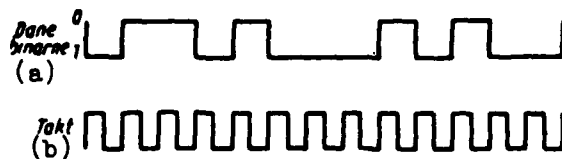


Fig. 3. Bit synchronization with the aid of clock strobing pulses

Key: (a) binary data
(b) strobing

The clock strobing pulse releases the two-stage shift register, to which data to be transmitted are delivered and the di-bits are determined by testing this register.

The modulating signals in channels P and Q are transmitted from coding systems to shaping systems, which ensure equal amplitude of signals at the outputs of the modulator, which is indispensable for generating a proper four-phase signal. These outputs to modulators pass low-pass filters, which are damped harmonically.

The output functions of the modulators are summed on the resistor and transmitted via a system of gates controlled by instructions from the interface. Fig. 4 illustrates the operational principle of four-phase difference modulation on the presented circuits in the form of a block diagram.

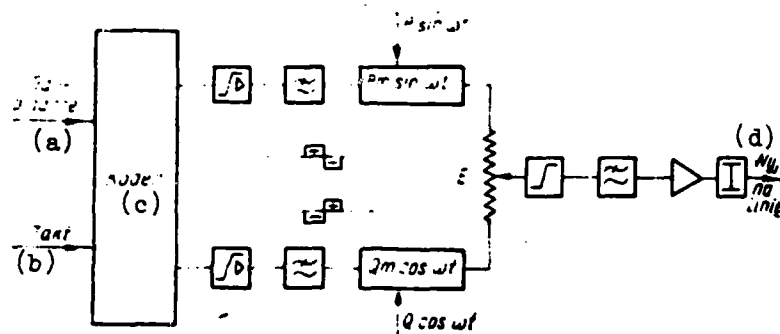


Fig. 4. Operational principle of four-phase difference modulation. Block diagram of transmitter

Key: (a) binary data
(b) strobing
(c) coding device
(d) to transmission line

4. Demodulator 2400 bits/s and decoder

The system operates on the reverse principle from that of the modulator to which it is similar; it also contains circuits for automatic regulation of the reception level and for recovery of the carrier frequency. Fig. 5 presents the block diagram of the modulator circuits with the decoder.

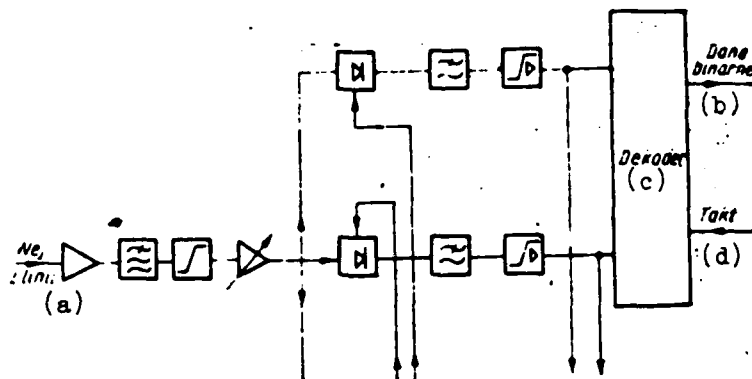


Fig. 5. Block diagram of demodulator and decoder circuits

Key: (a) from transmission line
 (b) binary data
 (c) decoder
 (d) strobing

It is possible to obtain a fourth-order component by transformation of the linear signal and selective filtering, i.e., a signal with a frequency four times greater than that of the carrier frequency, whose phase is invariable regardless of which of the four phase changes is received.

This phase-invariable signal is subdivided using frequency dividers into four signals for obtaining the carrier frequency. The local carrier frequency is obtained in this manner, which, although it may be in an arbitrary (one of the four) absolute phase, is related to the linear signal in such a way that it always undergoes a phase shift relative to the signal in the transmission line by a certain odd multiple of 45° ; hence, if the signal in the transmission line has one of the four phases shown in Fig. 2c, the recovered carrier frequency will have one of the four phases shown in Figs. 2a and 2b and the selection may be arbitrary.

To obtain the quadrature carrier frequency, a circuit shifting the phase by 90° is used, for example, if the main carrier frequency is phase P-, the quadrature frequency is phase Q+ (see Fig. 6). These two recovered carrier

frequencies are used to demodulate the linear signal exactly in a manner which is the opposite (reverse) of the operation of the modulator.

After amplification and filtering, the arriving signal is delivered to the circuits of the carrier frequency detector and to the amplifier, with automatically regulated amplification, ensuring a constant input level to detectors and to the circuit recovering the carrier frequency. The system recovering the carrier frequency that has been described above consists, above all, of a full-period rectifier, followed by the amplifier and the resonance circuit, which discards components beyond the range 3-4 kHz.

The output function is delivered to a second full-period rectifier, the output of which is coupled with the resonance circuit with high Q factor and $f=7.2$ kHz, which separates the component with an invariable phase and frequency which is four times greater than the carrier frequency f . The quadrature carrier frequencies are then obtained thanks to the frequency dividers. Fig. 7 illustrates the operational principle of detector circuits.

The output of the amplifier with automatic regulation of the level is also delivered to two detectors, which are very similar to the modulators of channels P and Q. They generate a linear signal. The output signals from these detectors are filtered in identical filters as in the modulator. The filter output signals are squared in difference amplifiers, on integrated circuits, and then transmitted as nonregenerated digital signals to the decoder and to synchronizing circuits in the control unit.

The decoder is released by reception strobing, which is equalized with passages of nonregenerated digital signals.

The decoder compares the binary states of the outputs of the detector during one signal element period with the states of the same outputs in the next following period by verifying the state of the two-stage shift register associated with each detector output.

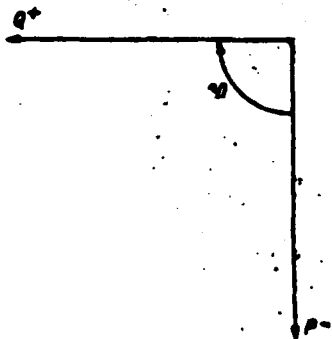


Fig. 6. Phase shift of carrier frequencies P and Q reproduced in receiver

These registers are strobed with the di-bit frequency. The check gate decisions set the states of the output shift register, which is strobed at the bit rate.

The end product is the received data flow (2400 bits/s).

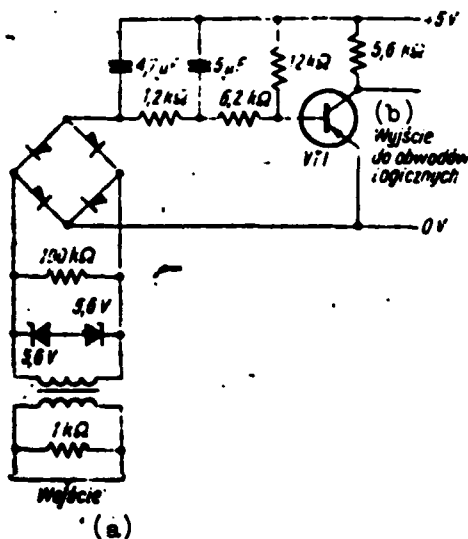


Fig. 7. Circuits of ring-shaped detector (MODEM DATEL)

Key: (a) input
(b) output to logic circuits

5. Strobing

Fig. 8 shows the block diagram of the strobing system. The system contains a quartz oscillator, which controls a series of dividers generating various input frequencies and 1.8 kHz quadrature carrier frequencies for the 2400 bits/s modulator. The strobing frequency is selected by signals on lines connecting the modem to a terminal (interface).

The transmitter strobe can be sampled either from a common strobing system block, or from an external source, for example, a terminal. The receiver strobe is sampled from a common strobing system block, but it must be equalized or synchronized with the passages of the received data signal arriving in the line.

Each passage through zero of data signals received from the demodulator causes generation of a pulse in the circuit of the generator of the receiver, at which time the phase of the generator signal is compared with the phase of the data signal.

Correlation of the phase takes place via circuits accelerating or delaying the phase of the carrier frequency generated in the receiver.

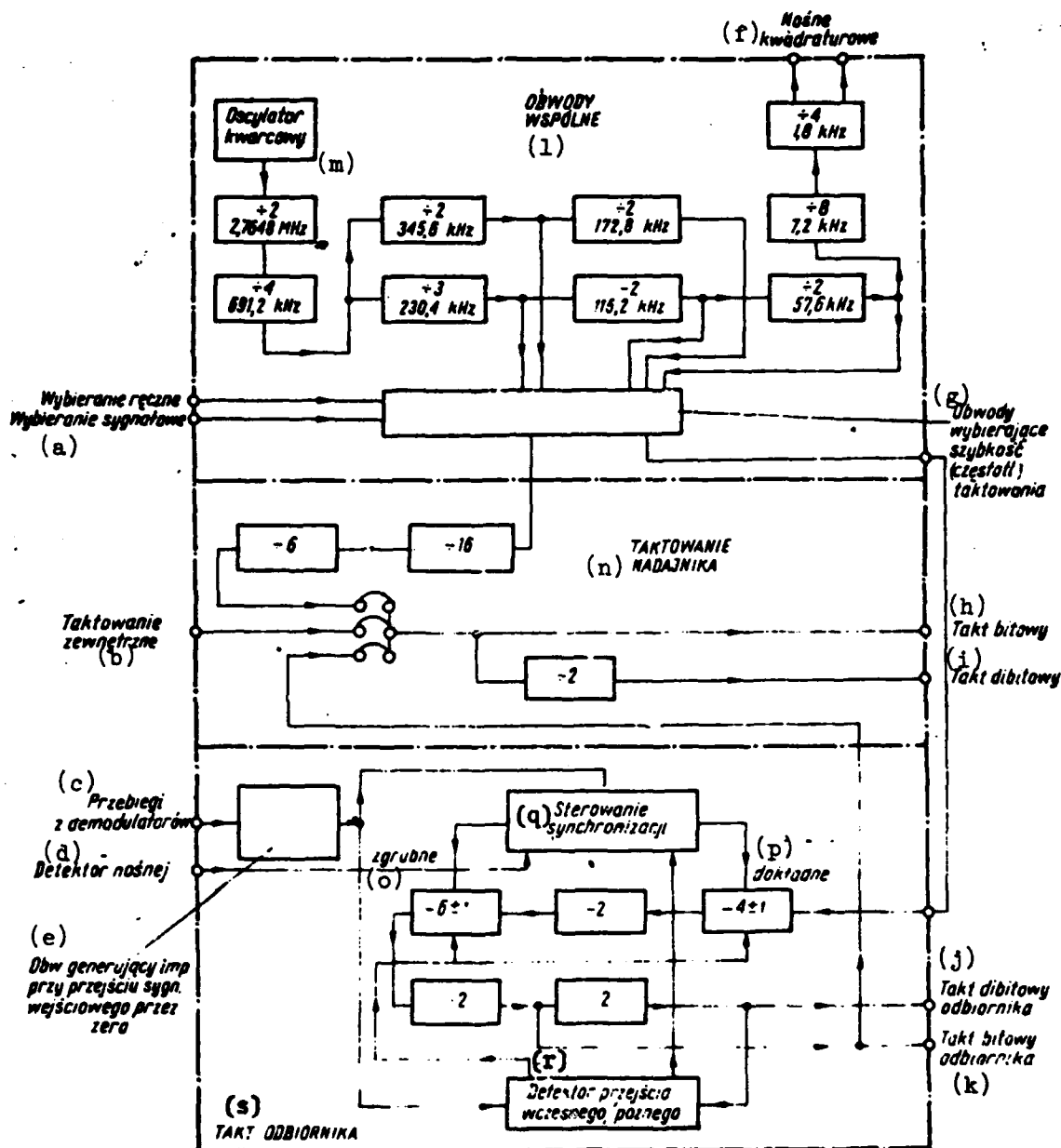


Fig. 8. Block diagram of strobing systems (MODEM DATEL)
 Key: (a) manual selection, signal selection; (b) external strobing;
 (c) signals from demodulator; (d) carrier frequency detector;
 (e) circuit generating pulse during passage of input signal through zero;
 (f) quadrature carrier frequencies; (g) circuits selecting strobing rates (frequency); (h) bit strobing; (i) di-bit strobing;
 (j) di-bit strobing of receiver; (k) bit strobing of receiver;
 (l) common circuits; (m) quartz oscillator; (n) strobing of transmitter; (o) rough; (p) exact; (q) synchronization control; (r) detector of early/delayed passage; (s) receiver strobing

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